A Modeling Study on Natural Convection in Emplacement Drifts and Its Impact on Drift Seepage

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RESEARCH OBJECTIVES

The decay heat outputs of the radioactive waste potentially to be emplaced at Yucca Mountain will strongly affect the thermal-hydrological (TH) conditions in and near the geologic repository. This decay heat elevates drift temperatures above ambient conditions. Pore formation water in the near-field rock mass evaporates into the open air spaces of the drift and is transported by natural convection processes from the hot drift center to the cool drift end (where no waste is emplaced) and condenses. Our goal is to better understand this reduction of moisture content in the near-drift fractured rock and its role in the potential reduction of seepage into the drift.

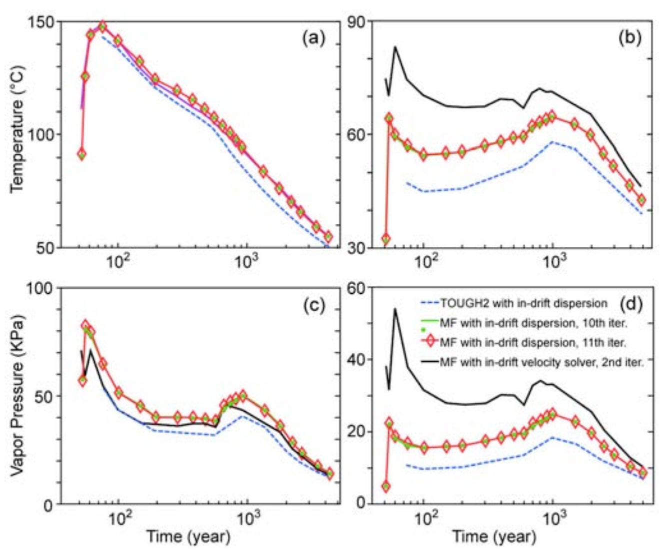

Figure 1. Drift wall temperature evolution at the hottest (a) and coldest (b) drift segments; and vapor-pressure evolution at the hottest (c) and coldest (d) drift segments.

APPROACH

A multiscale seepage modeling procedure was developed that accounts for transport processes in and between the fractured rock mass and the open air drift, two distinct domains. To fully account for 3-D effects, a first model (MF-T2) operates on a scale that encompasses the entire drift plus surrounding rock units. In MF-T2, the flow and transport processes in the rock mass are simulated with the multiphase, multicomponent simulator TOUGH2, and the in-drift heat and moisture flows are simulated with MULTIFLUX (MF), a lumped-parameter CFD (Computational Fluid Dynamics) code (Danko et al., 2007). MF provides an efficient iterative coupling technique for matching the mass and heat transfer between the rock mass and the drift. In addition, explicit modeling of the impact of in-drift moisture transport on seepage is being conducted with a separate high-resolution seepage model, with model inputs (in-drift temperature and relative humidity) provided by the full drift-scale MF-T2 model.

ACCOMPLISHMENTS

The new solution procedure has been applied to evaluate the heat-driven flow and transport processes in a representative emplacement drift at Yucca Mountain, embedded in a monolithic, three-dimensional rock mass. Two alternative approaches were tested to simulate in-drift natural convection: (1) a lumped-parameter CFD dispersion model and (2) a model explicitly simulating the air velocity distribution. Several iterations were completed, refreshing the MF results against TOUGH2 runs, with both solution procedures showing excellent convergence (Figure 1). Also, alternative results from a simplified in-drift model within TOUGH2 are shown (Birkholzer et al., 2006). High-resolution seepage model development is ongoing, with preliminary results indicating that strong natural convection processes can significantly reduce the near-field fracture moisture content, thereby reducing the seepage potential.

SIGNIFICANCE OF FINDINGS

The difficult task of coupling CFD models with porous media models, to understand moisture reduction in the near drift, is undertaken with a unique and efficient approach. Initial results from the coupled MF-T2 solution procedure show good convergence between the two domains for a full drift-scale representation. The ongoing efforts of applying results from these simulations into a high-resolution seepage model will allow for a better understanding of seepage reduction due to natural convection processes, thereby further characterizing potentially beneficial repository behavior.

RELATED PUBLICATIONS

Birkholzer, J., S.W. Webb, N. Halecky, P.F. Peterson, and G.S. Bodvarsson, Evaluating the moisture conditions in the fractured rock at Yucca Mountain—The impact of natural convection in heated emplacement drifts. Vadose Zone Journal, 5, 1172–1193, 2006.

Danko, G., D. Bahrami, and J.T. Birkholzer, The effect of unheated sections on moisture transport in the emplacement drift. Nuclear Technology (in press), 2007.

ACKNOWLEDGMENTS

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